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DESIGN AND IMPLEMENTATION OF THE HAZARD CONTROL BOX FOR THE RIDE MOTION SIMULATOR

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This report describes the design and implementation of the Computer Automated Measurement and Control (CAMAC) Hazard Control Box for use as an electronic safety device for the Ride Motion Simulator. This device uses comparitor circuitry to detect any exceeded position limit of the simulator, alert the operator, and halt the simulation immediately. The box is uniquely interfaced to a MicroVAX/CAMAC computer system through a change-of-state module. Other options to the box include a ramp down toggle switch, and an emergency stop electronic switch.

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PREFACE

This report was written as a supplement to the man-rating documents for the Ride Motion Simulator currently being developed at the U.S. Army Tank-Automotive Command. Any questions regarding the man-rating process for the Ride Motion Simulator are to be referred to the U.S. Army Tank-Automotive Command, ATTN: Analytical and Physical Simulation Branch, AMSTA-RYA, (Alexander Reid or Gregory Hudas), Warren, Mi., 48397-5000, Telephone: AV786-6676.

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1.0. INTRODUCTION

This report, prepared by the Analytical and Physical Simulation Branch of the Tank-Automotive Technology Directorate, describes the design and implementation of the Computer Automated Measurement and Control (CAMAC) Hazard Control Box for the Ride Motion Simulator (RMS). This Box is comprised of circuitry that serves as redundant electronic safety interfaces between the CAMAC computer system and the simulator as required by man-rating documents issued by the Surgeon General of the Army.

2.0. OBJECTIVE

The primary intent of this work was to effectively design and fabricate an electronic device to monitor the RMS position and alert the CAMAC system if any position limit is exceeded. To accomplish this task, comparitor circuits and other associated circuitry were developed and placed into a standard 19 inch rack mounted box. These circuits also provide a means for the CAMAC operator to either ramp down the RMS, or stop it immediately through an electrical emergency switch.

3.0. CONCLUSIONS

The CAMAC Hazard Control Box and associated circuitry discussed in this report serve as an electronic interface from the four degree of freedom RMS to the CAMAC computer system. Its primary responsibility is to detect when a position limit is exceeded and alert both the CAMAC computer and the RMS operator for further action.

The control panel of the box consists of two sets of red and green light emitting diodes (LEDs), representing upper and lower limits, for each of the four degrees of freedom of the RMS. If the RMS remains between its preset travel limits in each of the degrees of freedom, the corresponding green LEDs will be turned on. When the simulator exceeds either a lower or upper limit, the corresponding red LED will turn on and a 12 volt logic signal will be sent to the CAMAC which will cause the RMS to stop immediately.

Other features of the box include a "ramp down" toggle switch and an emergency stop push button switch. Both of these switches give the CAMAC/RMS operator redundant ways of bringing the physical simulation to a halt.

The circuitry is fabricated into a standard 19 inch rack mounted box. The inputs and outputs are BNC connectors. Coaxial cable is used as the cable connection between the hazard box and the CAMAC system.

4.0. RECOMMENDATIONS

The final design of the comparitor circuit of the RMS hazard box can be effectively modified in the future by replacing the resistor/operational-amplifier combination with a commercially available comparitor Integrated Circuit (IC) chip. This would provide for an easy means of debugging and replacing defective parts.

It is strongly recommended that another CAMAC hazard box be fabricated of the same design and attached to the full-scale motion base simulators to monitor the position signals for safety purposes. Though these simulators do not need to be man-rated, the box will provide an extra means of safety for the equipment.

5.0. DISCUSSION

5.1. Background

The Ride Motion Simulator (RMS) is a position driven system containing four independent degrees of freedom; linear motion along the vertical axis, and the three rotational motions of pitch, roll, and yaw about the lateral, longitudinal, and vertical axis respectively. (See Figure 5-1). The RMS has the maximum payload capacity of one man-sized crewstation, and its bandwidth reflects high performance standards (Refer to the Appendix for RMS specifications).

The RMS is controlled by a Computer Automated Measurement and Control (CAMAC) Computer System. The CAMAC system serves as a interface between a micro-Vax II computer workstation and the RMS. It outputs terrain position data in the form of voltage values to the RMS through a Digital-Analog Converter. Shown in Figure 5-2 is an example of a terrain file output from the CAMAC system to the simulator's vertical degree of freedom. The output contains a scale factor which is dependent upon the position limitations of each degree of freedom.

The CAMAC system has the ability to monitor the RMS through the CAMAC Hazard Control Box (refer to Figure 5-3). This box consists of comparitor circuitry which will detect an exceeded limit within the position signals coming from the RMS, alert the operator, and send a 12 volt logic error signal back to the computing system for further action. (See Figure 5-4). The hazard box also contains circuitry to drive the comparitor circuits, and ramp-down and emergency stop switches for use by the CAMAC/RMS operator. This section describes the design and workings of the CAMAC Hazard Control Box.

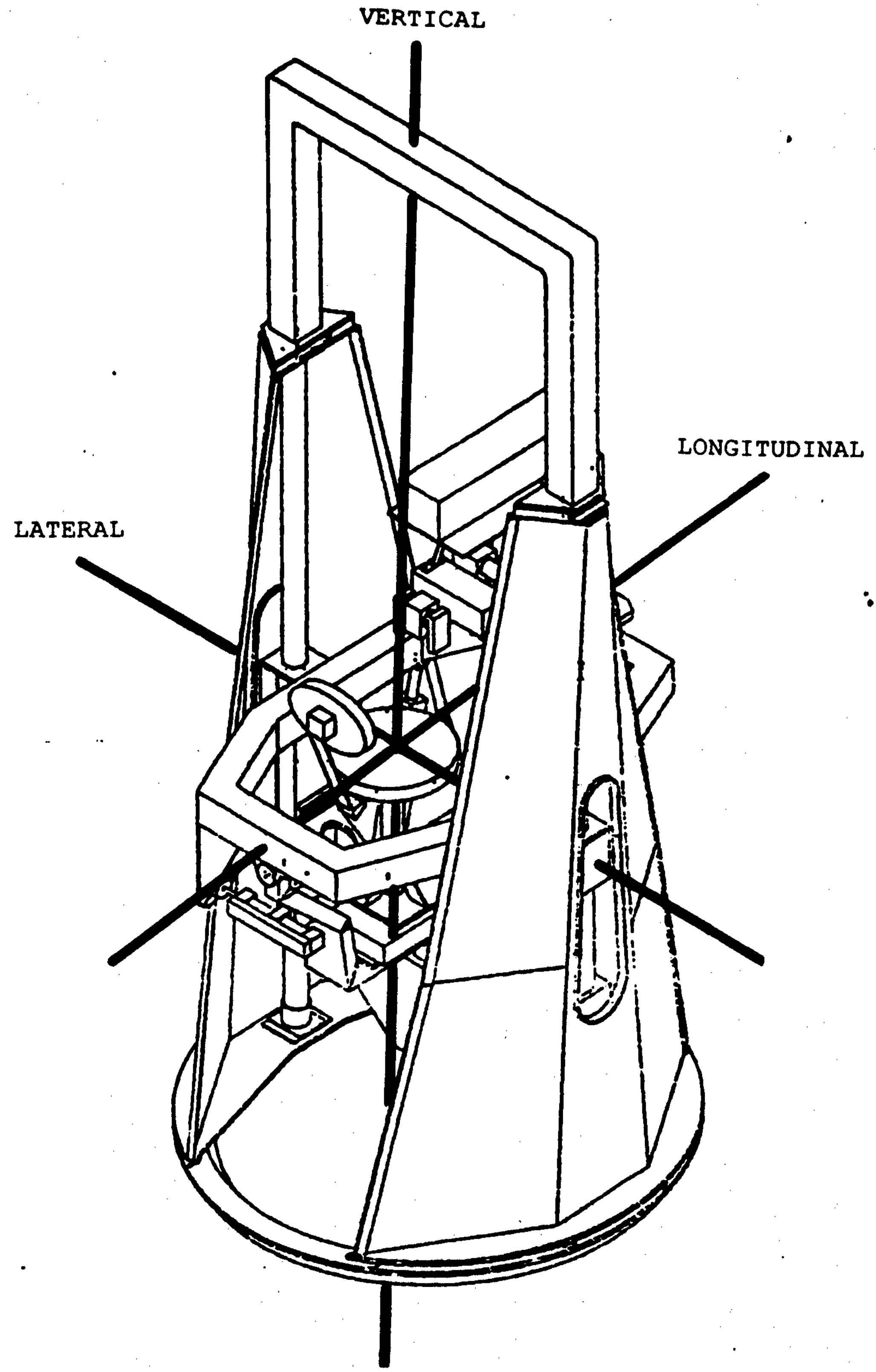


Figure 5-1. Ride Motion Simulator and Corresponding Motion Axes

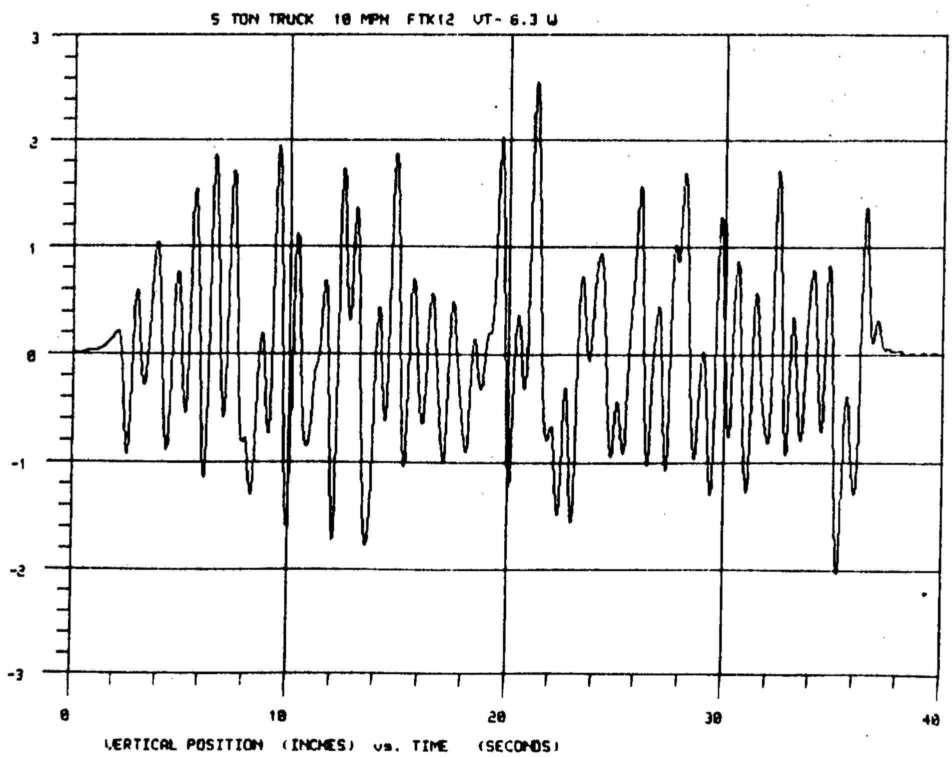


Figure 5-2. Example of a Terrain File Simulation for the RMS

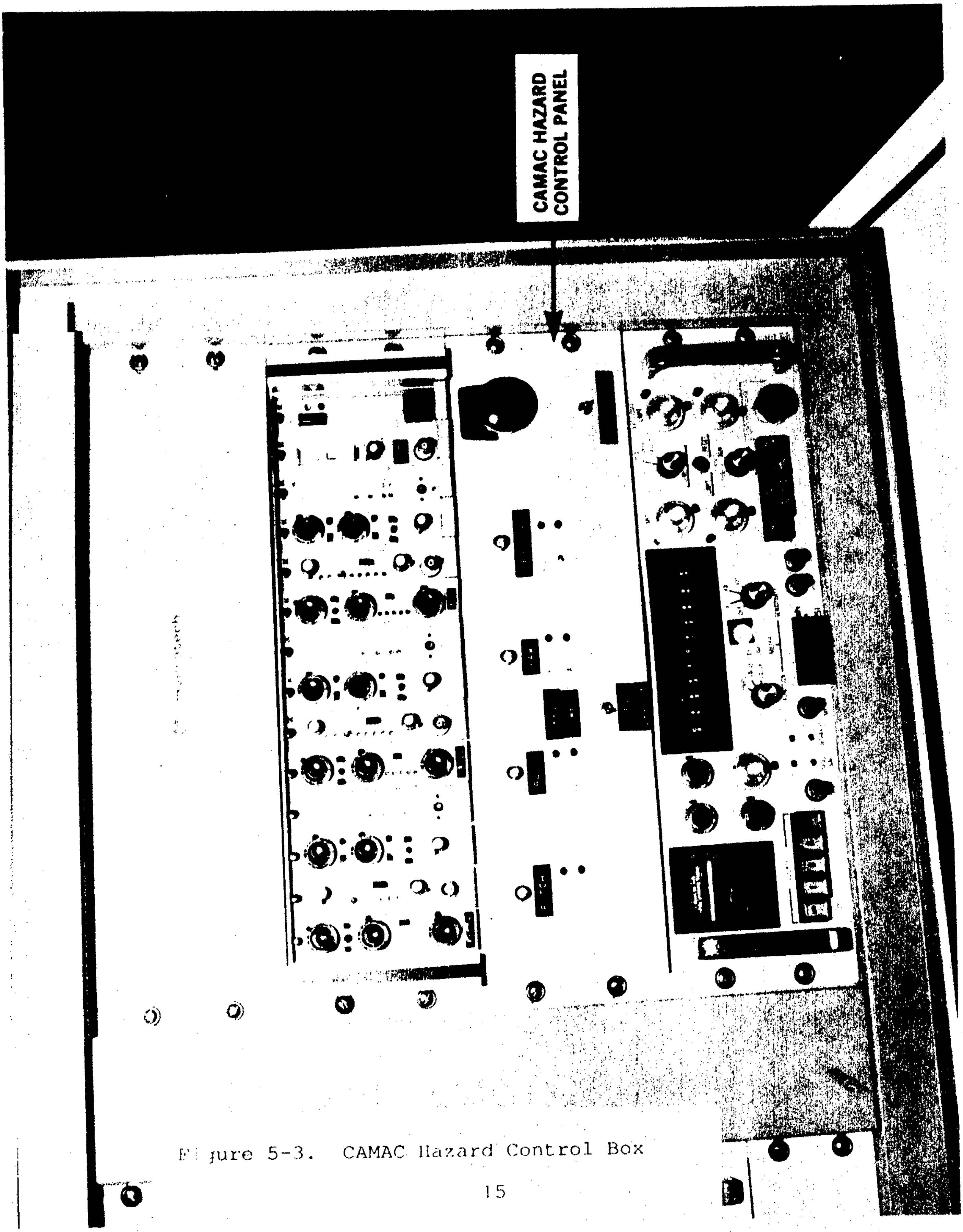


Figure 5-3. CAMAC Hazard Control Box

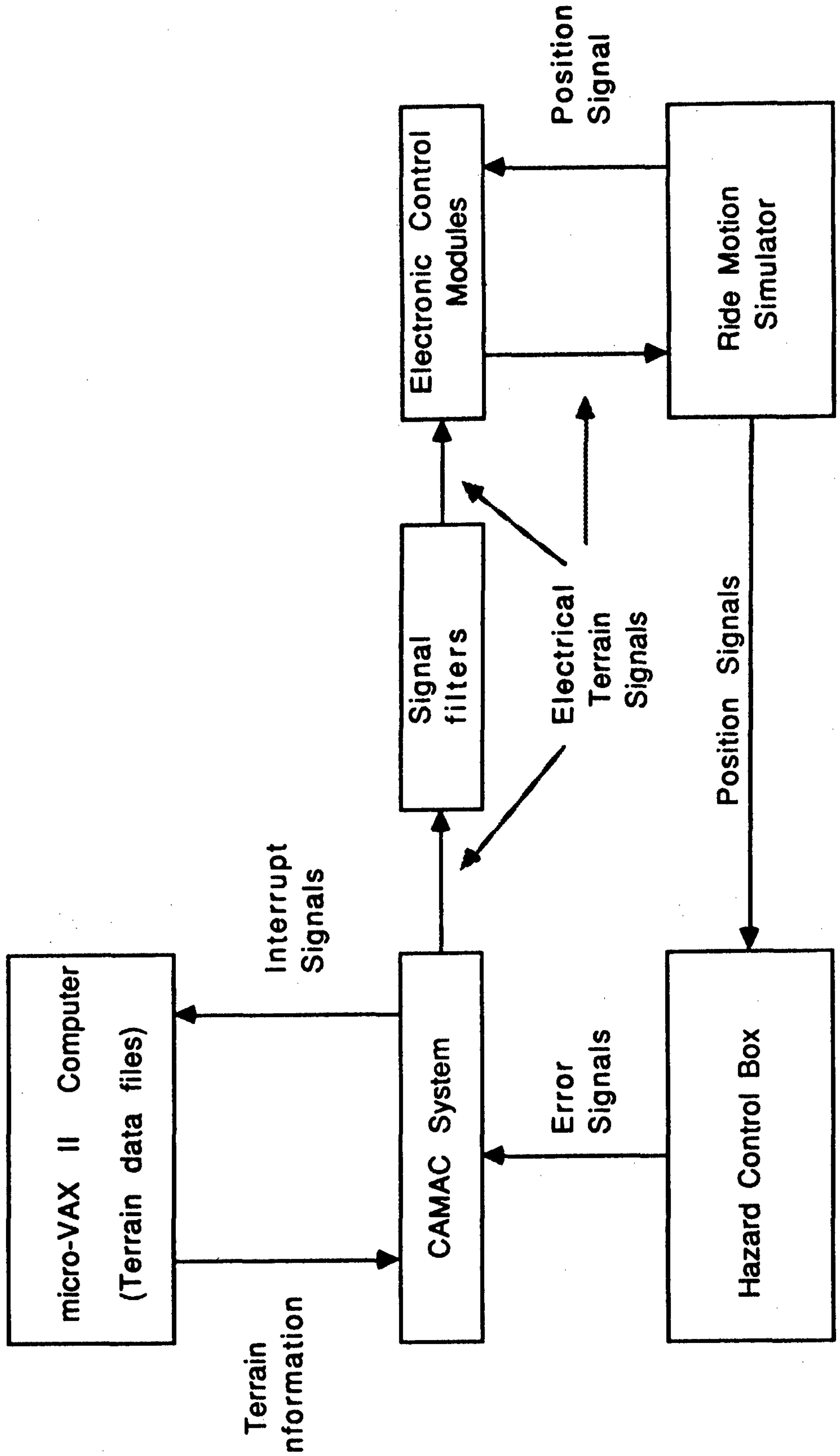


Figure 5-4. Signal Control Block Diagram

5.2. Comparitor Circuitry

Shown in Figure 5-5 is the basic schematic for the comparitor circuit located in the box. There are a total of four comparitor circuit cards representing the pitch, roll, yaw, and vertical degrees of freedom.

The first portion of the circuit consists of a signal conditioning filter. This is a second order Butterworth Low Pass filter with a cutoff frequency of approximately 50 Hz (refer to Figure 5-6). It is used to condition the position signal from the RMS to prevent any sizeable noise or spikes from entering the circuit.

After the RMS position signal has been conditioned, it enters comparitors representing the upper and lower limits of the particular degree of freedom. Table 5.1 illustrates the position limits and the corresponding voltage values for each degree of motion. The variable resistance potentiometers R_1 and R_2 are used for reconfiguration and fine tuning. The input signal is compared to the corresponding voltage limit. If the position signal exceeds the set limit, the polarity at the output of the operational-amplifier (op-amp) is positive. A voltage divider decreases the voltage to a Transistor-Transistor Logic (TTL) high signal which enters the $J\bar{K}$ Flip-Flop chip. If the position signal remains within the limit range, the output polarity after the op-amp is negative. The diode (7910A or 7839A) conducts and sinks the current into ground resulting in a TTL low signal entering the Flip-Flop.

The $J\bar{K}$ Flip-Flop (SN54376) normally operates by the function table illustrated in Table 5.2.[1] The primary purpose of the flip-flop is to serve as a latching device for the conduction of the red and green LEDs. To assist in this function, the output Q is fed back into the input $\bar{K}$.

If the input J is TTL high (signifying that a limit has been exceeded) and $\bar{K}$ is a TTL low (as a result of a clear), the output Q will toggle from low to high making $\bar{K}$ go high on the next positive-edge trigger. Once this happens, Q will remain a TTL high and is thus "latched" until a clear is given. The output from Q is then amplified through a comparitor/op-amp set up, drives the red LED, and is divided down to a 12 volt logic signal which will be sent to a change-of-state module of the CAMAC system. The RMS driver software detects this change of state and shuts down the simulation immediately.

On the other hand, if J is a TTL low (signifying normal simulator operation) and $\bar{K}$ is a TTL low (as a result of a

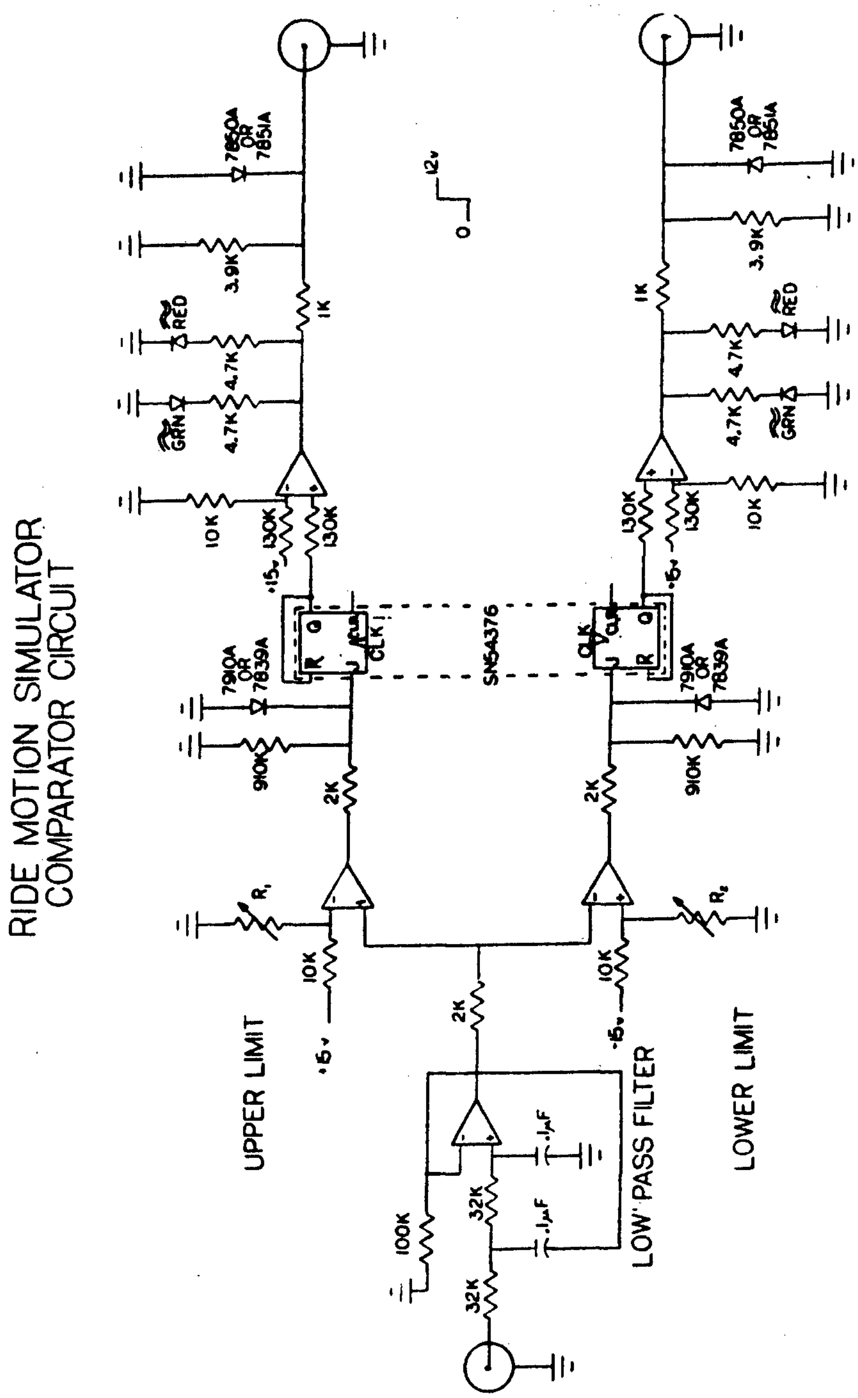


Figure 5-5. Schematic of the Comparitor Portion of the Hazard Control Box

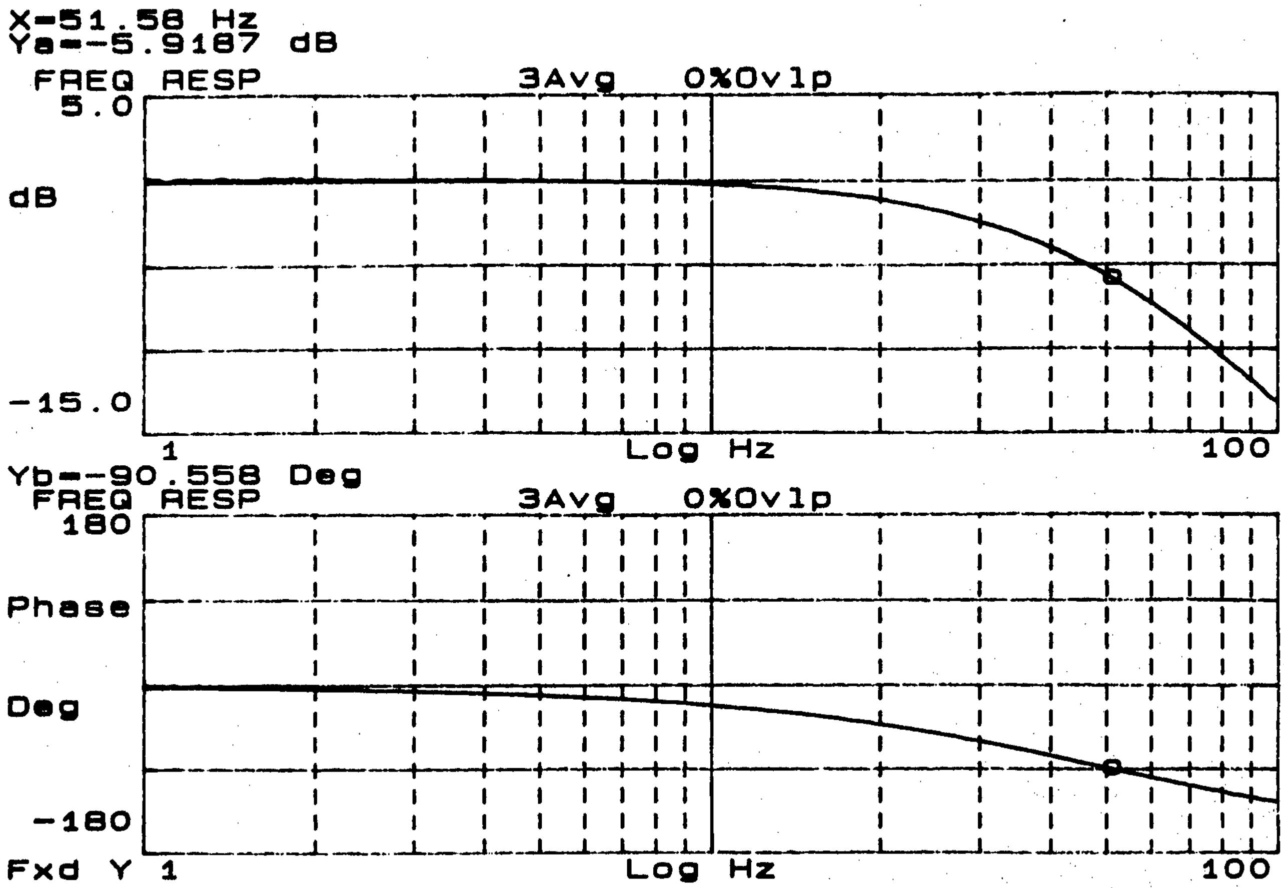


Figure 5-6. Frequency Response of the Second Order Butterworth Low Pass Filter with a break point at approximately 50 Hz.

Table 5.1 RMS Position Limits and Corresponding Voltage Values from Zero Static Position

Degree of Freedom	Position Limits		Voltage Values*	
	Upper	Lower	Upper	Lower
Vertical	+16 in	-16 in	+4.5 V	-3.7 V
Roll	+10 deg	-10 deg	+10 V	-10 V
Pitch	+12.5 deg	-12.5 deg	+10 V	-8.6 V
Yaw	+10 deg	-10 deg	+7.6 V	-7.8 V

*Voltage values were determined from limitation tests performed on the RMS

Table 5.2 Function Table for the J$\bar{K}$ Flip-Flop (SN53476)

Common Inputs		Inputs		Outputs
Clear	Clock	J	$\bar{K}$	Q
L	X	X	X	L
H	↑	L	H	Q_0
H	↑	H	H	H
H	↑	L	L	L
H	↑	H	L	TOGGLE
H	L	X	X	Q_0

clear), the output Q will be a TTL low and will remain low until J goes high. The Q output is amplified through a comparitor/op-amp set up, drives the green LED, and is divided down to a -12 volt signal which sinks into ground through a diode (7850A or 7851A). This results in a zero logic signal being sent to a CAMAC change-of-state module.

The direct clear status of the flip-flop is obtained through a toggle switch and a 5 volt source. All outputs from the flip-flop are fully buffered.

5.3. Clocking Circuit

The $J\bar{K}$ Flip-Flops, used in the comparitor circuits previously mentioned, synchronize the state changes during the positive edge of a clock pulse. The clocking circuit used in the CAMAC Hazard Control Box is an astable multivibrator designed by the integration of a Schmitt comparitor output with a RC low-pass combination (refer to Figure 5-7).[2] With the capacitor voltage applied to the inverted end of the op-amp, the resultant is a simple square-wave generator with a chosen frequency of 100 Hz and ΔV=11.0 Volts.

The required components for the generator circuit were calculated using the equation

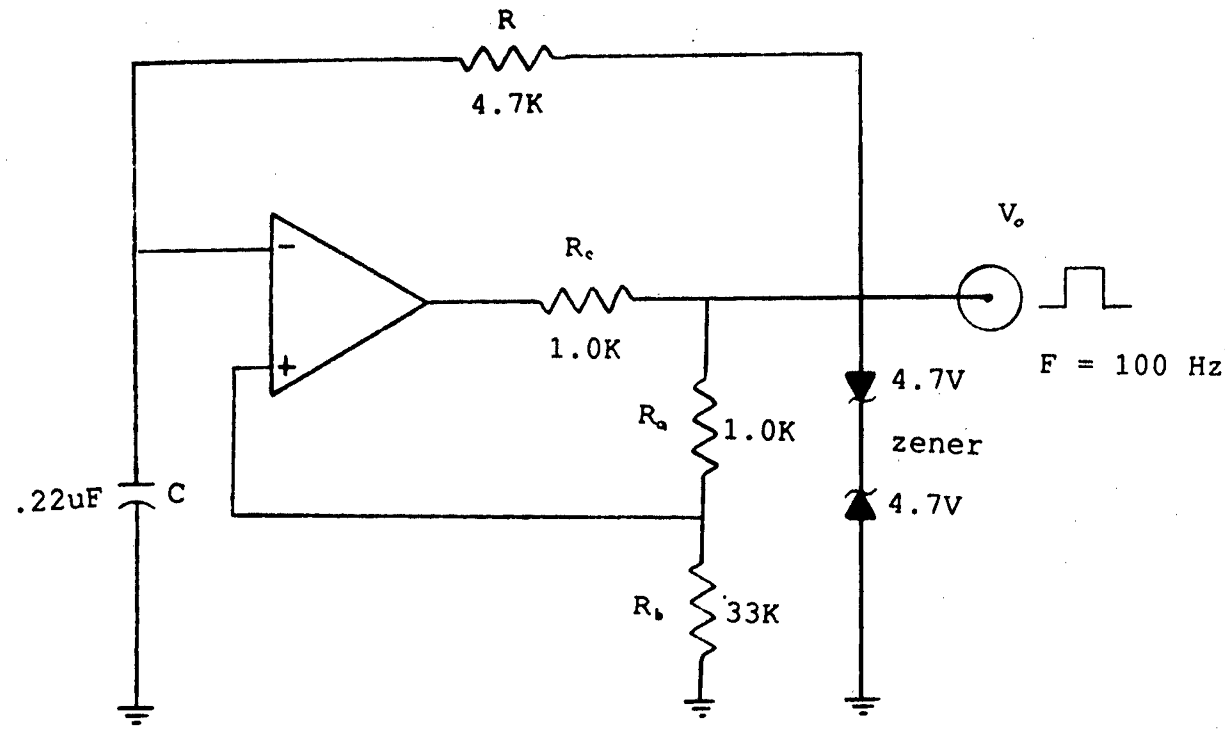
$$2RC \ln \frac{1+B}{1-B} = T$$

where $B = \frac{R_b}{R_a+R_b}$ is the feedback factor.

The zener diodes control the symmetry of the output sinewave.

5.4. Shutdown Switches

The CAMAC Hazard Control Box contains two electrical shutdown switches. The first switch is an emergency pushbutton switch which could be activated by the RMS operator. When this switch is pushed, a 12 Volt DC signal is sent to the CAMAC which freezes the RMS at its present orientation and position.



$$2RC \ln \frac{1+B}{1-B} = T$$

$$\text{Where } B \doteq \frac{R_b}{R_a+R_b}$$

Figure 5-7. Clocking Circuit for Hazard Control Box

The other switch is a ramp-down toggle switch. When activated, a +12 Volt logic signal is sent to a CAMAC Change-of-State module. The CAMAC responds by ramping the RMS down on the present iteration through a ramping function.

5.5. Power of the Circuitry

The comparitor and clocking circuitry of the CAMAC Hazard Control Box are powered up with the use of two separate voltage sources. First, a +/- 15 Volt, 350 mA, AC-DC power supply is used as a source to the op-amps, and as a reference for the comparitors. Second, +5 Volt AC-DC source is used to supply the $J\overline{K}$ Flip-Flop integrated circuit chips.

Both power supplies are decoupled at each op-amp and flip-flop chip with 1μF tantalum capacitors (Figure 5-8) to obtain a noise free environment.

5.6. Cabling and Grounding

The input and output connectors of the box are of BNC type. Both the rear and front panels are connected to chassis ground. Coaxial cable is currently being used but a balanced-pair system will be implemented in the near future. The grounding configuration of the coaxial cable is shown in Figure 5-9. Both the source and load ends are grounded to prevent any sizable voltage from being developed at the cable shield which also serves as the signal-return for the system.

Table 5.3 shows the cable hardware connection sequence from the Hazard Control Box to the CAMAC system through backpanel connections. The CAMAC monitors each one of these pin connections to detect any change-of-state and controls the RMS accordingly.

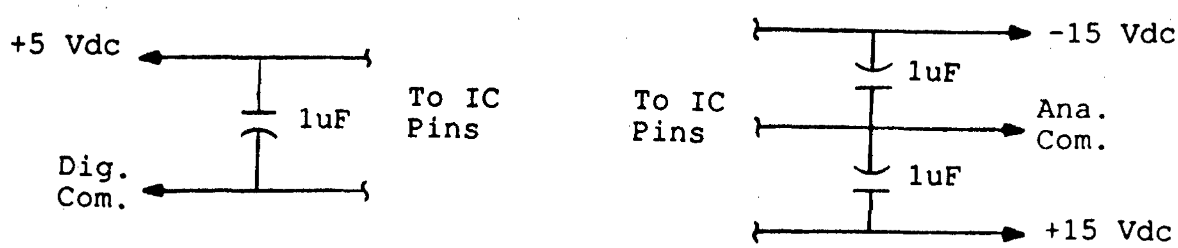


Figure 5-8. Power Supply Decoupling

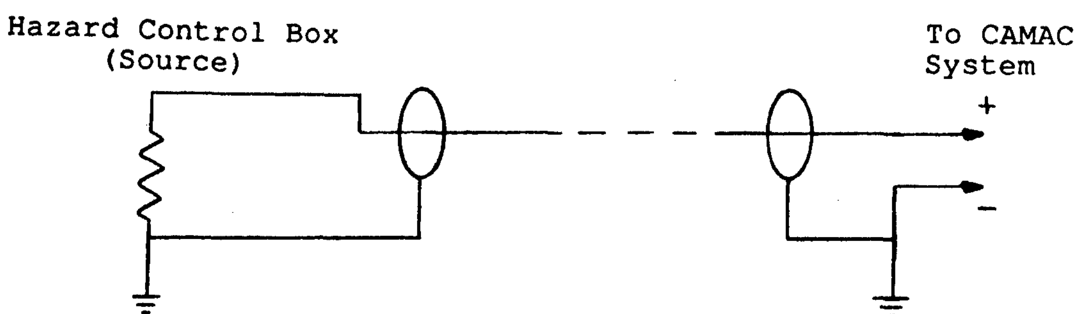


Figure 5-9. Coaxial Cable Grounding Configuration

Table 5.3 Hardware Connection Sequence from the Hazard Control Box to the CAMAC System

CAMAC Hazard Control Box		CAMAC System Backpanel
Emergency Shutdown	(Immediate)	Input Pin #1
Slow Shutdown	(Ramp-down)	Input Pin #11
Vertical Upper Limit	(Immediate)	Input Pin #3
Vertical Lower Limit	(Immediate)	Input Pin #4
Roll Upper Limit	(Immediate)	Input Pin #5
Roll Lower Limit	(Immediate)	Input Pin #6
Pitch Upper Limit	(Immediate)	Input Pin #7
Pitch Lower Limit	(Immediate)	Input Pin #8
Yaw Upper Limit	(Immediate)	Input Pin #9
Yaw Lower Limit	(Immediate)	Input Pin #10

LIST OF REFERENCES

[1]Texas Instruments, "TTL Data Book, Volume 2," Texas Instruments Inc., Dallas, TX, p. 3-1031 (1985)

[2]Millman, Jacob, "Microelectronics, Digital and Analog Circuits and Systems," McGraw-Hill, New York, NY, pp. 625-627 (1979)

SELECTED BIBLIOGRAPHY

Millman, Jacob, "Microelectronics, Digital and Analog Circuits and Systems," McGraw-Hill, New York, NY (1979)

Texas Instruments, "TTL Data Book, Volume 2," Texas Instruments Inc., Dallas, TX (1985)

APPENDIX

RIDE MOTION SIMULATOR SPECIFICATIONS

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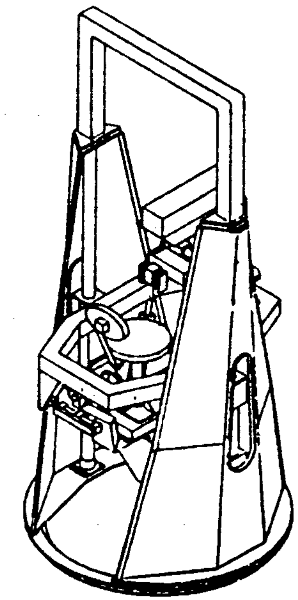

- STRUCTURE
  - DEGREE OF FREEDOM — 4 (VERTICAL, YAW, PITCH, ROLL)
  - PAYLOAD CAPACITY — 1 MAN-SIZED CREWSTATION
- PERFORMANCE (MAX.)
  - POSITION — VERT: ± 16 IN; YAW: ± 10 DEG; PITCH: ± 12.5 DEG; ROLL: ± 10 DEG
  - VELOCITY — VERT: > 60 IN/SEC,; YAW: 13 DEG/SEC; PITCH: > 80 DEG/SEC; ROLL: > 80 DEG/SEC
  - ACCELERATION — VERT: > 5.0 G'S; YAW: 370 DEG/SEC**2; PITCH: > 2600 DEG/SEC**2; ROLL: > 2600 DEG/SEC**2
  - BANDWIDTH — VERT: 6 Hz; YAW: 1 Hz; PITCH: 10 Hz; ROLL: 9 Hz
- GENERAL
  - CONTROL — CAMAC/MICROVAX SYSTEM (REAL-TIME)
  - DATA ACQUISITION — 64 CHANNEL A/D WITH SIGNAL CONDITIONING CAPABILITY
  - SAFETY — REDUNDANT SAFETY FEATURES USING PNEUMATIC, HYDRAULIC, AND ELECTRONIC DETECTION SYSTEMS

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